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TECHNOLOGY APPLICATION CENTER
THE UNIVERSITY OF NEW MEXICO
ALBUQUERQUE, NEW MEXICO 87131



HEAT PIPE TECHNOLOGY
A BIBLIOGRAPHY WITH ABSTRACTS

QUARTERLY UPDATE

APRIL-JUNE 1977

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THE HEAT PIPE INFORMATION OFFICE

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THE TECHNOLOGY APPLICATION CENTER
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ALBUQUERQUE, NEW MEXICO

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PREFACE

Heat Pipe Technology is a continuing bibliographic summary of research on heat pipes. The first volume was published in the Spring of 1971 and is cumulative through March of that year. The 1971, 1972, 1973 and 1974 Annual Supplements as well as the 1975 and 1976 Quarterly Update Series have been published and distributed. Additional copies are available from the Technology Application Center.

This update to Heat Pipe Technology cites the additional references identified during April, May and June of 1977. It is the second of the 1977 quarterly series intended to provide "current awareness" to heat pipe researchers.

A library containing essentially all of the articles and publications referenced in this update, and in all the previous volumes is maintained at TAC. Although a considerable effort has been made to insure that the bibliography is complete, readers are encouraged to bring any omissions to the attention of this office.

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GUIDE TO USE OF THIS PUBLICATION

A number of features have been incorporated to help the reader use this document. They consist of:

- A TABLE OF CONTENTS listing general categories of subject content and indexes. More specific coverage by subject title/keyword and author is available through the appropriate index.
- CITATION NUMBERS assigned to each reference. These numbers, with the prefix omitted, are used instead of page numbers to identify references in the various indexes. They are also used as TAC identifier numbers when dealing with document orders; so please use the entire (prefix included) citation number when corresponding with TAC regarding a reference. An open ended numbering system facilitates easy incorporation of subsequent updates into the organization of the material. In this system, numbers assigned to new citations in each category will follow directly the last assigned numbers in the previous publication. The citation number of the last reference on each page appears on the upper right-hand corner of that page to facilitate quick location of a specific term.
- A REFERENCE FORMAT containing the TAC citation number, title of reference, author, corporate affiliation, reference source, contract or grant number, abstract and keywords. The reference source tells, to the best of our knowledge, where the reference came from. If from a periodical, the reference source contains the periodical's title, volume number, page number and date. If for a report, the reference source contains the report number assigned by the issuing agency, number of pages and date.

--An INDEX OF AUTHORS alphabetized by author's last name. A reference's author is followed by the reference's citation number. For multiple authors, each author is listed in the index.

--An INDEX OF PERMUTED TITLES/KEYWORDS affords access through major words in the title and through an assigned set of keywords for each citation. A reference's title is followed by the reference's citation number. In the indexes, all the words pertaining to a reference are permuted alphabetically. Thus, the citation number for a reference appears as many times as there are major title words or keywords for that reference. The permuted words run down the center of an index page. The rest of the title or keywords appear adjacent to a permuted word. Since a title or set of keywords is allowed only one line per permuted word the beginning, the end, or both ends of a title or set of keywords may be cut off; or, if space permits, it will be continued at the opposite side of the page until it runs back into itself. A # indicates the end of a title or set of keywords while a / indicates where a title or set of keywords has been cut off within a line.

I. GENERAL INFORMATION, REVIEWS, SURVEYS

HP77 10002 HEAT PIPE THEORY AND PRACTICE (BOOK)

Chi, S.W., (George Washington University, Washington, DC), 256 p., 67 refs, 1976, Hemisphere Publ. Corp., Washington, DC; McGraw-Hill Book Co., NY, A77-14825
 Avail:TAC

The operating principles of heat pipes (HP) are described along with a discussion of different types of HP, and the underlying theory, design, and fabrication of HP. Working fluids, wick configurations, reservoirs, and pipe materials are dealt with, and cleaning, assembly, evacuation, charging, and closure of HP are covered. Capillary action, sonic limitation, entrainment limitation, boiling limitation, interface conditions, startup difficulties, and control and modulation of HP are discussed. Applications discussed include: heat exchangers, space heating, industrial processes, cryosurgery, heating/ventilation/air conditioning systems, de-icing, heat sinks, and thermal energy recovery. Practical numerical design examples are included in the text.

(DESIGN, FABRICATION, APPLICATIONS)

HP77 10003 HEAT PIPES

Kennedy, R.D., Silletto, J., Quest, V 1:39-52, Winter 1976-1977, A77-23372
 Avail:TAC

Limitations of conventional modes of transferring heat in a spacecraft are discussed. Attention is focused on a new type of device called the heat pipe, which in its simplest form is a type of reflux boiler. The principles of operation of both devices are outlined. The operation of a heat pipe is the same as in the reflux boiler except that the condensed liquid returns to the evaporator through capillary action in a wick instead of by gravity. Heat pipe versatility is discussed for various applications, with special emphasis on space applications. The development of a variable conductance heat pipe is described, along with its modification for closer temperature regulation by addition of a heater coil around the noncondensable gas reservoir and a temperature-control feedback circuit. The technology is not yet fully mature, but as more and more practical applications are found, that maturity will come. Other potential applications include the use of heat pipes for laser mirror cooling, heat transfer in solar energy systems, and coal gasification.

(APPLICATIONS, VCHP)

HP77 10004 HEAT PIPES AND THEIR TECHNICAL APPLICATIONS

Vasiliev, L.L., Inzhenerno-Fizicheskii Zhurnal, V 31:905-930, Nov 1976, A77-22413, In Russian
 A general review paper on heat pipes is presented with attention given to principles of operation. Also considered are transfer processes in heat-pipe wicks, the effect of the structural characteristics of a wick on convective transfer of the working fluid, and heat and mass transfer in the wicks of low-temperature heat pipes. Applications of heat pipes in such fields as energy and electrical technology are investigated with particular emphasis on the use of heat pipes in heat exchangers. The structural design of heat pipes is considered and different types of heat pipes are reviewed including gas-regulated pipes, pipes with regulated steam flow, pipes with regulated liquid flow, centrifugal heat pipes, multi-component pipes, screw-type heat pipes, two-phase gravitational heat pipes, coaxial heat pipes, and electrohydrodynamic heat pipes.

(REVIEW, WICKS, APPLICATIONS, DESIGN)

II. HEAT PIPE APPLICATIONS

II. A. GENERAL APPLICATIONS

HP77 20010 ENERGY CRISIS BROADENS HEAT PIPE APPLICATIONS

Behrens, C.W., ed., Ruzic, M.P., (NASA Technology Transfer Consultant), Appliance Manufacturer, p. 50-55, Apr 1977
 Avail:TAC

This report introduces several household applications of heat pipes such as heat recovery equipments for chimney flue gases, heat pipe griddle, frozen food thawing oven, deep-fat fryer, and ventilation system. Because of their efficient heat transfer capability, heat pipes hold great promise for reducing energy consumption in heating, cooling, ventilating, and also cooking.

(HEATING, COOLING, VENTILATION, COOKING, APPLIANCES)

HP77 20011 HEAT PIPES AND THEIR INSTRUMENT APPLICATIONS

Finlay, I.C., Green, D.B., (Energy Div., National Engineering Lab., Glasgow, Scotland), Journal of Physical Engineering, V 9:1026-1035, N12, 56 refs, 1976
 Avail:TAC

A review is given of the principal operating characteristics of heat pipes, and the factors governing their selection, design, and manuf. are discussed. The use of heat pipes to improve the performance of scientific instruments is described.

(DESIGN, MANUFACTURE)

HP77 20012 A SOLAR HOUSE WITH HEAT PIPE COLLECTORS

Gehrke, G., Energie-wirtschaftliche Tagesfragen, V 26:726-728, Dec 1976, A77-18598, In German

A description is given of a solar house project involving the installation of collectors on the roof of a residential house located at the outskirts of Essen in West Germany. The solar installation provides heating for a residential area of 190 sq m. Energy for hot-water supply system is also supplied. A heat storage system provides a heat reserve for days on which the amount of solar radiation is insufficient.

(WEST-GERMANY, HEATING, STORAGE)

HP77 20013 SOME MATERIAL CONSIDERATIONS INVOLVED IN THE APPLICATION OF SOLAR ENERGY TO ELECTRIC POWER GENERATION

Gervais, R.L., Taketani, H., Babel, H.W., Pittinato, G.F., (McDonnell Douglas Astronautics Co., Huntington Beach, CA), SAMPE Journal, V 12:12-19, N2, 1976
 Avail:TAC

A progress report on two of the major material tasks associated with solar electricity power is given. The activities and issues associated with the formation of noncondensable gases in water heat pipes are discussed together with some of the activities and issues associated with material selection and some fabrication considerations for the concentrator.

(NONCONDENSABLE-GASES, WATER, CONCENTRATOR)

HP77 20014 CHEMILUMINESCENT REACTIONS IN A HEAT PIPE OVEN

Hessel, M.M., Drullinger, R.E., Broida, H.P., (NBS, Boulder, CO), Journal of Applied Physics, V 46:2317-2318, N5, May 1975
 Avail:TAC

A heat-pipe oven has been used to contain and control the chemiluminescent reaction $\text{Ba} + \text{N}_2\text{O} \rightarrow \text{BaO} + \text{N}_2$. The heat-pipe oven permits Ba vapor to be maintained at any desired pressure. Reactions were easily controlled by varying the flow rate of N_2O or pressure of Ba. A large volume (about 20 cm³) of chemiluminescence was produced and spectra were taken from 0.1 to 5 torr. This device is well suited to the study and control of chemical reactions between metal vapors and oxidizers.

(SPECTRA, CHEMICAL-REACTIONS, METAL-VAPORS, OXIDIZERS)

HP77 20015 MEASUREMENTS OF SC I GF-VALUES

Parkinson, W.H., Reeves, E.M., Tomkins, F.S., (Harvard College Observatory and Smithsonian Astrophysical Observatory, Cambridge, MA), Royal Society, London, Proceedings, Series A, V 351:569-579, N1667, 19 refs, Dec 8, 1976, A77-16270
 Avail:TAC

Absolute gf-values were obtained for 98 transitions in neutral scandium by the hook method using an inductively coupled heat-pipe oven. Of the 98 lines, 51 are classified, 33 are unclassified lines that occur in pairs with the lower energy level identified, and 14 are unclassified but are believed to originate from one of the two lower levels of the ground state. The results are compared with semiempirical and other measurement results in the literature.

(OVEN, ENERGY-LEVEL)

HP77 20016 CERAMIC HEAT PIPE HEAT EXCHANGERS

Ranken, W.A., (Los Alamos Scientific Lab., NM), 8 p., Sept 1976, LA-6514-MS
Avail:TAC

High-temperature strength, resistance to corrosive atmospheres, and moderate cost combine to make ceramic materials an obvious choice for construction of high-temperature thermal energy recuperator systems. Despite these advantages, ceramic recuperators are steadily being replaced by metallic units at considerable sacrifice in maximum air or fuel preheat temperatures and hence in recovery efficiency. This is because existing ceramic designs contain a large number of cemented joints which, under the influence of differential thermal expansion and vibration, tend to open up and produce very large leakage rates between the exhaust and preheat streams. By constructing a recuperator from ceramic heat pipes, the number of joints and the thermal stress to which they are subjected can be greatly reduced, and very low leakage rates can, in principle, be obtained. Methods of fabricating ceramic heat pipes are described and a conceptual recuperator design is presented. Potential applications of this type of unit are also briefly discussed.

(RECUPERATOR, HEAT-RECOVERY, LEAKAGE, DESIGN)

HP77 20017 USE OF HEAT PIPES FOR HEAT SUPPLY OF HOTHOUSES

Sklyarenko, O.M., Berezovskii, V.A., Olanko, E.I., (USSR), San. Tekhnika. Resp. Mezhd. Nauch.-tekhn. Sb., V 16:47-48, 1976, In Russian
No abstract available

HP77 20018 GAS-FIRED HEAT PIPE VACUUM FURNACE

Stadelmann, M., Translated from Schweiz. Tech. Z., V 71:40-43, 6 p., Jan 17, 1974, ERDA-tr-211
Avail:TAC

A prototype natural gas-fired vacuum furnace for heat treatments and brazing was developed. A heat pipe is used to transfer heat from a compact high-temperature burner to the vacuum chamber. The furnace can be operated at temperatures up to 1037.5°C with a vacuum of 5×10^{-6} torr. The temperature is automatically controlled, and the fuel-air ratio is continuously monitored to optimize efficiency.

(HEAT-TREATMENTS, BRAZING, EFFICIENCY)

II. 3. THERMIONIC AND THERMOELECTRIC CONVERTERS

HP77 21000 HEAT PIPE NUCLEAR REACTOR FOR SPACE POWER

Koenig, D.R., (Los Alamos Scientific Lab., NM), 22 p., 1976, LA-UR-76-998
Avail:TAC

A heat-pipe cooled nuclear reactor was designed to provide 3.2 MW(t) to an out-of-core thermionic conversion system. The reactor is a fast reactor designed to operate at a nominal heat pipe temperature of 1675°K. Each reactor fuel element consists of a hexagonal Mo block which is bonded along its axis to one end of a Mo Li vapor heat pipe. The block is perforated with an array of longitudinal holes which are loaded with UO₂ pellets. The heat pipe transfers heat directly to a string of 6 thermionic converters which are bonded along the other end of the heat pipe. An assembly of 90 such fuel elements forms a hexagonal core. The core is surrounded by a thermal radiation shield, a thin thermal neutron absorber and a BeO reflector containing 30 loaded control drums.

(THERMIONIC-CONVERSION, FUEL, CORE)

HP77 21001 HEAT PIPE REACTORS FOR SPACE POWER APPLICATIONS

Koenig, D.R., Ranken, W.A., Salmi, E.W., (Los Alamos Scientific Lab., NM), American Institute of Aeronautics and Astronautics, Conference on the Future of Aerospace Power Systems, St. Louis, MO, Paper No. 77-491, 3 p., 12 refs, Mar 1-3, 1977
Avail:TAC

A family of heat pipe reactors design concepts has been developed to provide heat to a variety of electrical conversion systems. Three power plants are described that span the power

range 1-500 kWe and operate in the temperature range 1200-1700°K. The reactors are fast, compact, heat-pipe cooled, high-temperature nuclear reactors fueled with fully enriched refractory fuels, UC-2rC or UO₂. Each fuel element is cooled by an axially located molybdenum heat pipe containing either sodium or lithium vapor. Virtues of the reactor designs are the avoidance of single-point failure mechanisms, the relatively high operating temperature, and the expected long lifetimes of the fuel element components.

(FUELS, MOLYBDENUM, LIQUID-METALS, AEROSPACE APPLICATIONS, NUCLEAR SYSTEMS)

II. C. AEROSPACE ORIENTED APPLICATIONS

HP77 22006 TEST PROGRAM FOR TRANSMITTER EXPERIMENT PACKAGE AND HEAT PIPE SYSTEM FOR THE COMMUNICATIONS TECHNOLOGY SATELLITE

DePauw, J.F., Reader, K.E., Staskus, J.V., (NASA, Lewis Research Center, Cleveland, OH), NASA-TM-X-3453, 38 p., Nov 1976, N77-11268
Avail:TAC

The test program is described for the 200 watt transmitter experiment package and the variable conductance heat pipe system which are components of the high-power transponder aboard the Communications Technology Satellite. The program includes qualification tests to demonstrate design adequacy, acceptance tests to expose latent defects in flight hardware, and development tests to integrate the components into the transponder system and to demonstrate compatibility.

(VCHP, TESTS, TRANSPONDER)

HP77 22007 PERFORMANCE EVALUATION OF THE ESA HEAT PIPES INCLUDED IN THE INTERNATIONAL HEAT PIPE EXPERIMENT (IHPE) Final Report

Muenzel, W.D., (Stuttgart Univ., West Germany), 88 p., June 1976, ESA-CR(P)-855, N77-16301
Avail:TAC

In October 1974, heat pipes containing acetone and ammonia were tested in a zero g environment onboard a Black Brant sounding rocket as part of the International Heat Pipe Experiment. The preflight performance tests, the performance in flight, and tests performed after flight are described. The various results are compared.

(ACETONE, AMMONIA, ROCKET, TESTS)

HP77 22008 DEVELOPMENT OF A THERMAL DIODE HEAT PIPE FOR CRYOGENIC APPLICATIONS

Quadrini, J.A., (Grumman Aerospace Corp., Bethpage, NY), McCreight, C.R., (NASA, Ames Research Center, Moffett Field, CA), AIAA, Aerospace Sciences Meeting, 15th, Los Angeles, CA, Paper No. 77-192, 12 p., 10 refs, Jan 24-26, 1977
Avail:TAC

The paper describes the development of a cryogenic thermal diode heat pipe for space flight applications. The diode has ethane working fluid, and uses the liquid blockage technique with an internal blocking orifice, to accomplish shutoff in the reverse mode. The pipe is 0.635 cm OD by 75.82 cm long including a 2.54 cc excess liquid reservoir. Experimental data are presented for forward mode throughput vs tilt, film coefficients, and reverse mode characteristics. Transport capacity is 1000 w-cm at 2.5 cm tilt. Evaporator and condenser film coefficients were 0.92 and 1.64 w/sq cm K, respectively.

(ORIFICE, TILT, FILM-COEFFICIENTS)

HP77 22009 RADIATIVE TRANSFER AND THERMAL CONTROL

Smith, A.M., ed., (ARO, Inc., Arnold Air Force Station, TN), AIAA Progress in Astronautics and Aeronautics, V 49:567, 1976, A77-22919

The present collection of papers is concerned with advances in surface system radiation, gaseous radiation, solar collectors, thermal conductivity and contact resistance, and heat pipes, with particular reference to aerospace technology. Basic concepts are presented in predicting and measuring the radiative performance of materials and surfaces under various environmental conditions. Radiation and radiative transport in planetary atmospheres are discussed, along with theoretical studies of radiation problems regarding planetary entry of meteors and space probes. Other topics of interest include numerical modeling of flat-plate solar collectors, analytical models for lunar soil thermal conductivity, and bubble formation in arteries of gas-controlled heat pipes.

(SOLAR-COLLECTORS, THERMAL CONDUCTIVITY, CONTACT-RESISTANCE)

HP77 22010 DEVELOPMENT OF THERMAL CONTROL METHODS FOR SPECIALIZED COMPONENTS AND SCIENTIFIC INSTRUMENTS AT VERY LOW TEMPERATURES (FOLLOW-ON) Final Report Mar 31-Nov 30, 1976

Wright, J.P., Wilson, D.E., (Rockwell International Corp., CA), NASA-CR-150152, 103 p., Nov 1976, N77-15347
Avail:TAC

Many payloads currently proposed to be flown by the space shuttle system require long-duration cooling in the 3 to 200°K temperature range. Common requirements also exist for certain DOD payloads. Parametric design and optimization studies are reported for multistage and diode heat pipe radiator systems designed to operate in this temperature range. Also optimized are ground test systems for two long-life passive thermal control concepts operating under specified space environmental conditions. The ground test systems evaluated are ultimately intended to evolve into flight test qualification prototypes for early shuttle flights.

(SHUTTLE, DESIGN, OPTIMIZATION, RADIATOR)

II. D. NUCLEAR SYSTEMS

No Citation in Update, June 30, 1977

II. E. ELECTRICAL AND ELECTRONIC APPLICATIONS

No Citation in Update, June 30, 1977

III. HEAT PIPE THEORY

III. A. GENERAL THEORY

HP77 30003 FLIGHT DATA ANALYSIS AND FURTHER DEVELOPMENT OF VARIABLE-CONDUCTANCE HEAT PIPES

Eninger, J.E., Edwards, D.R., Luedke, E.E., (TRW Systems Group, Redondo Beach, CA), NASA-CR-137953, 52 p., Nov 1976, N77-14374

Avail:TAC

The work focuses on the mathematical modeling of three critical mechanisms of heat-pipe operation: (1) the effect that excess liquid has on heat-pipe performance; (2) the calculation of the dryout limit of circumferential grooves; (3) an efficient mathematical model for the calculation of the viscous-inertial interaction in the vapor flow. These mathematical models are incorporated in the computer program GRADE 11, which is described.

(MODELING, EXCESS-LIQUID, DRYOUT-LIMIT, VAPOR-INTERACTION, COMPUTER PROGRAM)

HP77 30004 GENERATION OF GAS DURING THE LONG-TERM OPERATION OF HEAT PIPES

Gil, V.V., Minkovich, E.N., Shnyrev, A.D., (Inst. Teplo-Massobmena im. Lykova, Minsk, USSR), Inzh. Fiz. Zh., V 31:594-600, N4, 1976, In Russian

The reasons for gas formation in low-temperature heat pipes operating for long periods are examined. H-containing substances (e.g., water, Me_2CO , NH_3) were used. Of the 3 possible reasons for gas generation thermal dissociation takes place only above the boiling point. Chemical dissociation of the tube material and electrochemical dissociation of the liquid are the other reasons, of which the latter becomes the determining factor during long-term operation. A method is given for calculating the amount of noncondensing gas generated, depending on the operation time. Good agreement of predicted and experimental values are obtained at 323-523°K.

(THERMAL-DISSOCIATION, CHEMICAL-DISSOCIATION, ELECTROCHEMICAL-DISSOCIATION, NONCONDENSING-GAS)

HP77 30005 AN INVESTIGATION OF CONDENSATION HEAT TRANSFER IN A CLOSED TUBE CONTAINING A SOLUBLE NONCONDENSABLE GAS Final Report

Saaski, E.W., Hanson, R.J., (Washington State Univ., Pullman, WA), NASA-CR-149095, 92 p., 1976, N77-10463

Avail:TAC

A more exact one-dimensional condensation heat transfer model for insoluble gases was developed and compared with experimental data. Modifications to this model to accommodate soluble gas behavior were also accomplished, and the effects on gas front behavior demonstrated. Analytical models for condensation heat transfer are documented, and an optical method used for measuring gas concentration profiles is outlined. Experimental data is then presented and interpreted.

(MODEL, GAS-FRONT, OPTICAL-METHOD)

HP77 30006 THE ANALYSIS OF THE TEMPERATURE REGIMES OF THE OPERATION OF A GAS-REGULATED HEAT PIPE

Shekrladze, I.G., Arkanlia, Z.V., Zhorzholiani, G.I., Iopuria, I.I., (Nauchno-Issledovatel'skii Institut Stabilnykh Izotopov, Tiflis, Georgian, USSR), Teplofizika Vysokikh Temperatur, V 14: 1126-1129, 6 refs, Sept-Oct 1976, A77-17924, In Russian

The operational heat regimes of a gas-regulated heat pipe are analyzed assuming the temperature and concentration of the buffer gas to vary along the heat pipe. It is further assumed that the temperature of the hot buffer gas is close to that of steam saturation, and the geometry of the heat pipe, surface heat transfer coefficients, the temperature of the ambient medium, and the mass of the inert gas injected into the pipe are all given. Pressure drops in the pipe are neglected and the thermodynamic parameters of the gas are described by an ideal-gas equation of state. The method employed can also be used to take account of longitudinal heat conduction of the wetted wick and of the outside ribbing.

(BUFFER-GAS, PRESSURE-DROPS, WICK)

HP77 30007 DETERMINATION OF FLOW VARIABLES IN THE EVAPORATOR OF A NONUNIFORMLY-HEATED HEAT PIPE

Tolubinskiy, V.I., (Eng Thermophysics Inst., Acad. of Science, USSR), Shevchuk, Ye.N., Chistopyanova, N.V., Journal of Assoc. Comput. Mach., V 7:74-78, N5, Sept-Oct, 1975, English Translation

A set of differential equations for determining the pressure, velocity, temperature and density distributions of vapor along a heat-pipe evaporator as a function of heat-flux nonuniformity is derived. The set is convenient for computer solution. Results of numerical solution are presented.

(PRESSURE, VELOCITY, TEMPERATURE, DENSITY, COMPUTER)

HP77 30008 STUDY OF CRYOGENIC GAS-REGULATED HEAT PIPES

Vasiliev, L.L., Konev, S.V., (USSR), V. sb., Teplo massobmen-b., V 3:232-233, 1976, In Russian
No abstract available

III. B. HEAT TRANSFER

HP77 31001 HEAT TRANSFER ANALYSIS OF A ROTATING HEAT PIPE CONTAINING INTERNAL AXIAL FINS

Corley, R.D., (Naval Postgraduate School, Monterey, CA), Master thesis, 71 p., June 1976, N77-16307
Avail:TAC

An analytical study was undertaken to determine the two-dimensional wall conduction effects in an internally finned, rotating heat pipe. The finite element method was employed to generate computer results for a copper condenser with triangular fins. Heat transfer rates were shown to be approximately seventy-five percent greater than those predicted by an earlier, one-dimensional analysis. Heat transfer rates were found to be insensitive to rotational speed and fin half-angle. Due to numerical difficulties within the finite element program, no data was obtained for the finned, stainless steel condenser.

(FINITE-ELEMENT, HEAT-TRANSFER-RATE)

HP77 31002 EFFECTS OF ONE-SIDED HEAT INPUT AND REMOVAL ON AXIALLY GROOVED HEAT PIPE PERFORMANCE

Kamotani, Y., (NASA, Goddard Space Flight Center, Greenbelt, MD), AIAA, Aerospace Sciences Meeting, 15th, Los Angeles, CA, Paper No. 77-191, 6 refs, Jan 24-25, 1977
Avail:TAC

The performance of an axially grooved heat pipe with one-sided heat input and removal was investigated analytically. Under zero-g condition the maximum heat transport of the pipe may decrease as much as 30% depending on the liquid slug behavior in the condenser section. In one-g environment the performance depends mainly on the fluid charge. The maximum heat transport, if over-charged, is almost equal to the value for uniform heating and cooling due to puddling effect. However, for some heater-cooler combinations the temperature drop across the heat pipe becomes very large. Computed results for tilted heat pipes compare favorably with available experimental data.

(HEAT-TRANSPORT, PUDDLE, TILT)

III. C. FLUID FLOW

HP77 32002 INVESTIGATION OF PERFORMANCE LIMITS IN AXIAL GROOVE HEAT PIPES Final Report

Feldman, R.T., Jr., (Univ. of New Mexico, NM), NASA-CR-137912, 42 p., July 1976, N77-11340
Avail:TAC

The entrainment-shear performance limit which occurs in axial groove heat pipes was investigated and explained. In the existing heat pipe literature the entrainment heat flux limit is defined as the condition where the Weber number is greater than or equal to one. In this analysis, the critical value for the entrainment Weber number is found to be 2 Π , less than or equal to 3 Π . Perhaps more important to the heat pipe designer than the entrainment performance limit is the prediction of the performance degradation due to vapor-liquid shearing stress which is also described. Preliminary qualitative experiments were conducted to observe the shear stress wave formation phenomena. The equations presented may be used to predict and minimize the vapor-liquid shear stress performance effects that occur in axial groove and puddle flow artery heat pipes.

(ENTRAINMENT, SHEAR, WEBER-NUMBER, WAVE, PUDDLE-ARTERY)

IV. DESIGN, DEVELOPMENT, AND FABRICATION

IV. A. GENERAL

HP77 40005 STUDY OF HEAT PIPES WITH EXTENDED SURFACES FOR THE REMOVAL OF HEAT FROM THE BULK OF AN AGITATED LIQUID

Vernikov, E.M., Frolov, V.F., Romankov, P.G., (USSR), Zh. Prikl. Khim., Leningrad, V 49:2110, N9, In Russian

An analytical expression is presented for determining the suitable applications of a heat pipe as an intermediate heat carrier with a high utilization coefficient of the heat-transfer agent. Heat pipes with the evaporation sections in the form of hollow, longitudinal fins with screen capillaries and disks with threaded capillaries were examined. A design method for a heat-transferring device with a disk evaporation section is presented.

(HEAT-TRANSFER, UTILIZATION-COEFFICIENT)

HP77 40006 STATUS OF DEVELOPMENT AND APPLICATION OF GAS-STABILIZED HEAT-PIPE RADIATORS

Koch, H., (Dornier-System GmbH, Immenstaad, West Germany), Deutsche Gesellschaft für Luft- und Raumfahrt, Jahrestagung, 9th, Munich, West Germany, Paper 76-192, 28 p., Sept 14-16, 1976, In German

The employment of a noncondensable gas in heat pipes makes it possible to obtain a certain control effect which can be used for the stabilization of the component temperature. The functional characteristics of gas-stabilized heat-pipe radiators are discussed and basic physical relationships are examined. A description of various gas-stabilized heat pipe designs is presented. Applications considered are related to gas-stabilized heat-pipe radiators for an output multiplexer and for communications satellites of the MAROTS or OTS type.

(CONTROL EFFECT, STABILIZATION, FUNCTIONAL-CHARACTERISTICS)

IV. B. WICKS

HP77 41008 DETERMINATION OF THE BASIC CHARACTERISTICS OF THE WICKS OF HEAT PIPES

Mukhammetdurdyeva, O., Berdyev, M., Toiliiev, K., (Turkmenskii Gosudarstvennyi Universitet, Ashkhabad, Turkmen SSR), Akademiia Nauk Turkmenkoi, Izvestiia, Seriia Fiziko-Tekhnicheskikh, Khimicheskikh i Geologicheskikh Nauk, p. 66-70, 6 refs, N5, 1976, In Russian

Experiments were conducted on three types of metallic mesh wicks for heat pipes: two of brass and one of steel. The objective was to determine values of capillary permeability, maximum height of fluid elevation in the porous wick, and effective heat conductivity for the three wicks and to compare these values with computed results.

(METALLIC-MESH, EXPERIMENTAL-RESULTS)

HP77 41009 DESIGN CONSIDERATIONS FOR CAPILLARY HEAT PIPES AT CRYOGENIC TEMPERATURES

Sukhia, S.P., Coletta, G.C., Pellow, H.C., (Massachusetts Inst. of Tech., Oak Ridge, TN, School of Chemical Engineering Practice), 36 p., Oct 13, 1976
Avail:TAC

A cryogenic heat pipe has been suggested as an efficient means of transferring heat from a cooled component on a spacecraft. A thermodynamic analysis of the heat pipe operation, at cryogenic temperatures, leads to the conclusion that the radiant heat leak into the system establishes a minimum temperature difference for efficient operation - the criterion being the absence of fluid boiling in the wick. A design equation for the maximum heat transport in the wick is presented and correlations for wicking characteristics and wick dimensions are established. A preliminary design for the spacecraft heat pipe is presented. Operating conditions and physical dimensions of the heat pipe and wick are specified. Possible wick materials and configurations are discussed, and a specific approach for experimentation is recommended.

(THERMODYNAMIC-ANALYSIS, HEAT-TRANSPORT, WICKING)

HP77 41010 COMPUTER PROGRAM GRADE 2 FOR THE DESIGN AND ANALYSIS OF HEAT-PIPE WICKS

Eninger, J.E., Edwards, D.K., (TRW Defense and Space Systems Group, Redondo Beach, CA), NASA-CR-137954, 114 p., Nov 1976, N77-14375
Avail:TAC

This user's manual describes the revised version of the computer program GRADE(1), which designs and analyzes heat pipes with graded-porosity fibrous slab wicks. The revisions are: (1) automatic calculation of the minimum condenser-end stress that will not result in an excess-liquid puddle or a liquid slug in the vapor space; (2) numerical solution of the equations

describing flow in the circumferential grooves to assess the burnout criterion; (3) calculation of the contribution of excess liquid in fillets and puddles to the heat-transport; (4) calculation of the effect of partial saturation on the wick performance; and (5) calculation of the effect of vapor flow, which includes viscousinertial interactions.

(GRADED-POROSITY, NUMERICAL SOLUTION, BURNOUT)

IV. C. MATERIALS

HP77 42001 HEAT PIPE MATERIALS COMPATIBILITY Final Report

Eninger, J.E., Fleischman, G.L., Luedke, E.E., (TRW Systems Group, Redondo Beach, CA), NASA-CR-135069, 49 p., Jan 1976, N77-12182
 Avail:TAC

An experimental program to evaluate noncondensable gas generation in ammonia heat pipes was completed. A total of 37 heat pipes made of aluminum, stainless steel and combinations of these materials were processed by various techniques, operated at different temperatures and tested at low temperature to quantitatively determine gas generation rates. In order of increasing stability are aluminum/stainless combination, all aluminum and all stainless heat pipes. One interesting result is the identification of intentionally introduced water in the ammonia during a reflux step as a means of surface passivation to reduce gas generation in stainless-steel/aluminum heat pipes.

(STAINLESS-STEEL, ALUMINUM, GAS-GENERATION)

HP77 42002 THE ELIMINATION OR CONTROL OF MATERIAL PROBLEMS IN WATER HEAT-PIPES. Semiannual Progress Report, Jan 1-June 30, 1975

Pittinato, G.F., (McDonnell Douglas Astronautics West, Huntington Beach, CA), 41 p., July 1975
 Avail:TAC

A description is given of research and development efforts conducted on water heat pipes from January 1 to June 30, 1975. The heat pipe life tests for the various candidate materials were continued. The copper and nickel alloys showed a constant high level of performance, while the ferrous alloys, excluding 430 SS, continued to undergo a slow performance recovery process. Diffusion calculations indicated that permeation of hydrogen gas through the heat pipe walls is a feasible mechanism for explaining the performance recovery process. A post test analysis of one heat pipe from each candidate material was initiated after 102 days of testing. Solid particles were found in the water contained by the Monel 400 and CDA 715 pipes. A scanning electron microscopy study of the oxide on the inside surfaces of the heat pipes revealed that the most tenacious and protective oxide formed on the 316 SS. Eleven additional heat pipes were fabricated and are presently being prepared for testing. These new tests include heavy walled, self-venting, and cost reduction heat pipes.

(COPPER-NICKEL, FERROUS ALLOYS, PERFORMANCE-RECOVERY)

V. TESTING AND OPERATION

HP77 50012 TRANSPORT CHARACTERISTICS OF A HEAT PIPE WITH WATER, METHANOL, AND FREON 113 AND SOME CHARACTERISTICS OF ITS OPERATION

Asakavicius, I., Gaigalis, V., Eva, V.K., V sb., Teplomassoobmen-b, V 3:216-222, 1976, In Russian
No abstract available

HP77 50013 DETERIORATION IN HEAT PIPE PERFORMANCE WITH EXCESS WETTING FLUID

Srivastava, R.M., (Univ. of Roorkee, India), Varma, H.K., Sharma, R.C., V 3:387-392, N5, 3 refs.
Sept-Oct 1976
Avail:TAC

An experimental investigation has been carried out to study the effect of the wetting fluid on the performance of an adiabatic heat pipe having water-cotton-wick matrix in a copper container. It has been found that when the wetting fluid charge increases beyond a certain limit, rapid decrease in the heat transfer rate occurs.

(HEAT-TRANSFER, WATER, COTTON-WICK)

HP77 50014 TEST OF HEAT PIPE UNDER SPACE CONDITIONS

Gil, V.V., Vasil'ev, L.L., Zharikov, N.A., Zelenin, V.E., Syvorotka, O.M., Uvarov, E.I., (Inst. Teplo-II Massobmena im. Lykova, Minsk, USSR), Inzh.-Fiz. Zh., V 31:990-995, N6, 1976, In Russian

The results of testing a heat pipe mounted on the space vehicle Intercosmos-11 during its operation in interplanetary space are given together with a brief description of the heat pipe. Freon-11 was the working fluid. The operating conditions were: working temperature -5 to +50°C heat flux 10 W at temperature drop <50°C, and heat flux difference between the heated and cooled parts of 0.25 W/cm². With a temperature drop along the pipe length of <2-3°C, total heat flux <20 W was ensured. The results obtained in weightlessness were compared with those obtained with a model in a barochamber on earth. Relatively good agreement was obtained.

(WEIGHTLESSNESS)

HP77 50015 EXPERIMENTAL STUDY OF A COAXIAL HEAT PIPE WITH EXCESS LIQUID

Konovalov, A.S., Intensif. Protseessov Perenosa Energ. Veshchestva Poristyykh Sredakh Nizk. Temp., V 51, N5, 1975, In Russian

The performance of a vertical coaxial, heat pipe was examined experimentally with water. Results are given in graphs for the temperature distribution along the evaporation convection sections at different throughputs through the annulus. Experimental results were expressed by $ek = 0.214(GrPr)^{0.2}$, valid for the flooded part of the annulus, where $ek = \lambda ek/\lambda$, λek is the thermal condition, taking account of convection, λ the thermal condition without taking account of convection, Gr and Pr are the Grashof and Prandtl nos., resp., and $GrPr = 10^6-10^7$. The mean value of the outer and inner diameters of the tubes forming the annulus is taken as the characteristic length.

(TEMPERATURE-DISTRIBUTION, HEAT-TRANSFER)

HP77 50016 INVESTIGATION OF FLOW AND INTERNAL HEAT TRANSFER IN POROUS FIBER MATERIALS

Letiagin, V.G., Khalatov, A.A., Shchukin, V.K., Baigaliev, B.E., Kostornov, A.G., Shevchuk, M.S., (Kazanskoi Aviatsionnyi Institut, Kazan, USSR; Akademiia Nauk Ukrainskio SSR, Institut Problem Materialovedeniia, Kiev, Ukrainian SSR), Teplofizika Vysokikh Temperatur, V 14:412-415, 9 refs, Mar-Apr 1976, In Russian

The paper describes the experimental investigation of the internal heat transfer of a porous metallic material - monodisperse nickel fibers with a diameter of 200 micrometers and a length of 9 mm prepared into disks with a diameter of 30 mm and a thickness of 6.95 to 10.1 mm - during coolant flow through the material. Data on the dependence of the analog of the coefficient of friction of the material on the Reynolds number reveals a laminar flow regime in the specimens examined. Specimens were induction-heated, and the temperature of the inner and outer surface of the specimens and coolant temperature in front of and in back of the specimens were measured by Nichrome thermocouples. These data were used to determine the internal heat transfer coefficients.

(WICK MATERIALS, FLOW REGIME)

HP77 50017 HOMOGENEOUS AND ARTERY WICK CRYOGENIC HEAT PIPES: ANALYSIS AND DEVELOPMENT

Pauluis, G., (McGill University, Canada), 1976
Avail:TAC

Cotter's analysis of the capillary limit in heat pipes is modified by introducing an irreversible interphase transfer pressure drop. The method is applied to homogeneous-, annular-, artery-, and hybrid wick structures. Prior cryogenic heat pipe reports are analyzed and differences between theoretical and practical limits are discussed. A test installation is described

in which the equipment is computer controlled and the data acquisition completely automated. The constructional details of three heat pipes are given. A thick - homogeneous - wick heat pipe was operated with oxygen and nitrogen as working fluids. Its predicted and observed capillary limits are in good agreement. Large radial temperature differences were observed. The onset of a film boiling regime was shown. Unsuccessful attempts have been made to run a nitrogen artery wick heat pipe despite many modifications made in the structure. The failure is attributed to poor liquid distribution in the evaporator.

(HYBRID-WICK, CONSTRUCTION, MODIFICATIONS)

HP77 50018 NUCLEATE BOILING IN THIN LIQUID FILMS

Rivers, A.D., Mackenzie, D.K., Marto, P.J., (Dept. of Mech. Engr. Naval Postgraduate School, Monterey, CA), Paper No. 16, presented at the American Institute of Chemical Engineers, 16th National Heat Transfer Conference, St. Louis, MO, Aug 8-11, 1976

Avail:TAC

Experimental results are presented for distilled water, ethyl alcohol and Freon-113 at atmospheric pressure with liquid levels ranging from pool depths of 25 mm down to thin films near 0.5 mm. Pool boiling data compare favorable with the Rohsenow correlation. Temperature measurements with thermocouples and liquid crystals show that liquid level has little effect on the heat transfer coefficient above a level of 5 mm. Below this level however, there is an increase of up to 50 percent in the heat transfer coefficient as the level is reduced, until dryout occurs. All the thin film data compare satisfactorily with the proposed correlation of Nishikawa.

(HEAT-TRANSFER-COEFFICIENT, HEAT-TRANSFER)

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